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Dyeing of Cotton / Nylon Blended Fabric to a Solid Shade in One Bath

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Abstract - Cotton / Nylon blended fabrics are normally dyed by two-bath or one-bath two-step dyeing method. This paper deals with dyeing nylon/cotton blends to a solid shade in one bath using one dye. In this study, the fabric treated with chloroacetic acid (CAA), to form the anionic form followed by the cationization form using the inorganic salt of magnesium chloride. The effect of treatments on dyeability, fastness, and few physicochemical properties has been investigated, and results are presented. The dyed fabric featured excellent tone-in-tone effects and color fastness, and the process featured shortened time and saved cost.

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I. Introduction

Egypt is the largest producer in Africa and worldwide of long (LS) and extra long staple (ELS) cotton, accounting for 50 percent of world production in 2009, it has built a brand reputation for its quality of cotton, 2010.

Blending is a complicated and expensive process, but it makes it possible to build in a combination of properties that are permanent, Gupta et al. 2007. Not only are blend used for better serviceability of fabrics but they are also used for improved appearance and hand. Blends of synthetic fibres with natural fibres offer the most valuable possibilities for combining desirable physical properties, because the two components are so dissimilar. Different fibres can be blended in textile structures to obtain the desirable properties of each of the fibres in the blend.

A blended yarn or fabric generally displays an averaging of the properties of the constituent fibres. When properly combined with cotton, nylon adds strength, which allows the development of unusually fine 'textures' and nylon provides smoothness, silkiness, and dirt rejection. It also reduces the weight of the fabric and increases its wrinkle resistance. The cotton gives softness and moisture absorption. If the combination is not properly balanced, the cotton may shrink, causing the fabric to pucker. Also the nylon fibers may cut the cotton fibers. A blend of at least 17% high-tenacity nylon staple with cotton can make a very durable fabric, Bloom, 2011.

Tactel (TCI) Nylon/Cotton blends have been strongly promoted in sports wear. Good solidity of hue and depth is more critical in 50:50 blends and in union fabrics, such as nylon warp stretch fabrics, containing cotton or nylon/ cotton wefts for swim wear and narrow fabrics, crimped nylon warp/viscose filament dress wear, or cotton warp/nylon weft constructions for uniforms, rain wear or work wear. Nylon/cotton is also used in socks.

There are various possibilities regarding the choice of dye classes for solid effects on nylon/cellulosic blends. Direct, acid, and reactive dyes are the most widely used anionic dyes for cotton, Koushic & Sonia, 2010.

Cellulose fibers when immersed in water produce a negative zeta potential and most of the dye classes suitable for cotton are anionic in nature. The negative charge on the fiber repels the anionic dye ions and consequently the exhaustion of the dye bath is limited. However this zeta potential can be easily offset by salt concentrations of about 10.000 – 100.000 ppm which cause environmental problems. But in the absence of these electrolytes a large part of the dye remains unexhausted and gets discharged in the effluent stream. To overcome these problems cationization of cotton has been studied by Chavan et al, 1998. Cationization of cotton is emerging as an effective tool that solves the environmental problems associated with dyeing of cotton with anionic dye, Subramanian et al. 2006.

Nylon being a polyamide contains many amide groups in its structure. It also contains free amine groups at the ends of its polymeric chains, although the number of these free amine groups is less than the number of carboxylic groups, and therefore, the fiber possesses a negative charge unless in the appropriate pH region. These amide and amine groups provide excellent hydrogen bonding sites and are the main factors contributing to the substantively of the dye molecules, Baig, 2010.

Apart from fastness considerations, the choice of dye system is much influenced by blend construction. Single-class methods are mainly used where the nylon is minor component, the nylon occupying the interior or the reverse side of the construction. Reserve, shadow and limited contrast effects are practicable on nylon/cellulosic blends, but seldom encountered in practice. Most acid dyes have very little affinity for cotton, but cationic cotton can be dyed readily with acid dyes. The ammonium groups act as dye sites.

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Therefore, with blended fabrics or mixed fabrics, using cationic cellulosic fiber and regular cotton, two-tone effects can be obtained in one-bath dyeing. Meanwhile, this phenomenon gives a possibility to one-bath dyeing for blended fabrics, using cationic cellulosic fiber and nylon, Draper et al. 2003.

Dyeablitity of cationized cotton and a nylon 6 fabric using acid dyes was described by Badawy et al. 2011. One-bath dyeing of cotton-nylon mixture with reactive and acid dyes was mentioned by Shang Run-ling. Anionic dyes such as direct, reactive, acid and solubilized sulfur dyes are attracted by the cationic charges imparted to the fabric by the cationic agent. Bright hues with excellent fastness can be achieved on nylon/cellulosic blends using reactive dyes. Some control over the distribution between nylon and cellulose is possible by selection of dyebath pH, temperature and electrolyte concentration.

Nylon is favored at low applied depths but the distribution shifts in favor of the cellulosic fiber as the saturation level of nylon is approached. The facility to attain high wet fastness standards on nylon/cellulosic blends by a one-bath technique at mildly acidic pH is a substantial advantage over the two-bath or two-stage procedures based on reactive dyes, Hook & Welham, 1988.

The main objective of this research is the ability to dye cotton/nylon blends in one step, one dyeing bath after the treatment of the fabric with the anonic chloroacetic acid followed by the cationization of the fabric with magnesium chloride. The process featured shortened time and saved cost.

II. Materials and Methods

The fiber properties of long staple Egyptian cotton variety Giza 86 selected to blend with nylon 6,6. Giza 86 was measured in Cotton Research Institute (CRI) labs by HVI spectrum instrument, The Cotton Research Institute Quality Test Corp 2010. The cotton samples were spun to 20s, with twist multiplier "4.0 T.M. using the olfil RST machine, this spinning technique was carried out according to the conventional method used at the experimental spinning mill. All of those yarns produced under controlled atmospheric conditions of 20°C± 2 temperature and 65% ± 2% Relative humidity. The produced yarn properties of Giza 86 and nylon 6,6 materials were shown in Table1.

Table1 : The produced yarn properties of Giza 86 and nylon 6, 6

Yarn properties of Giza 86	Yarn properties of nylon 6, 6
Thick places1	linear density 940 dtex
Thin places 0	Number of filaments 140
Neps 1	Breaking force 79.5 N
Elongation % 7.41	Breaking tenacity 844 mN/tex
C.V % 11.57	Elongation at break 17.9 %
Tenacity 20.22	Elongation at specified force9.6 %
----------	Hot air shrinkage 3 min. at 80°C were 5.1 %

a) Production of Cotton/ Nylon knitted fabric

Yarn samples were suitably waxed and identically knitted into single jersey fabric with the same construction on a flat knitting machine, half jacquard dymant machine Model 1987 from Italy. Goge 10 with 10 needles per inch and width is 100 cm. This was followed by Cairo Secondary School for spinning and weaving. Cotton and nylon yarns were blended in the carding stage with knitting flat machine as 5 different ratios as follows: 100% cotton, cotton / nylon 75 :25 %, cotton / nylon 50 :50 %, cotton / nylon 25:75 % and 100 % nylon.

b) Chemicals

All of chemicals used were of analytical grad and used without purification.

c) Treatment processes

Scouring and bleaching of cotton/nylon blend

The blended samples were scoured and bleached according to the process botained by Karmakar, S. R (1999).

d) Treatment of blended cotton-nylon with chloroacetic acid(CAA)

Treatments of the blended samples with CAA were carried out as shown in the following equation according to Hashem et al. 2003.

$$ClCH_2COO^- + Cell.\text{—}OH \longrightarrow Cell.\text{—}O\text{—}CH_2COO^- + HCl$$

The carboxylic acid group content of the partially carboxymethylated cellulosic fabrics were determind according to the method descibed by J. William 1984, and It was found that the carboxylic contents were 114.54.

e) Cationization of blended cotton-nylon with magnesium choride

Blended fabrics were treated by magnesium chloride as shown in Figure 1, using pad dry cure procedure. The solutions were prepared as follows 40.6g (0.2 mole) from magnesium chloride hexahydrate

dissolved in 400 ml of deionized water. It yielded to 0.5M of aqueous $MgCl_2$ solution. The pad dry cure application method was applied and followed by washing and drying according to Mustafa Bilgin, 2005.

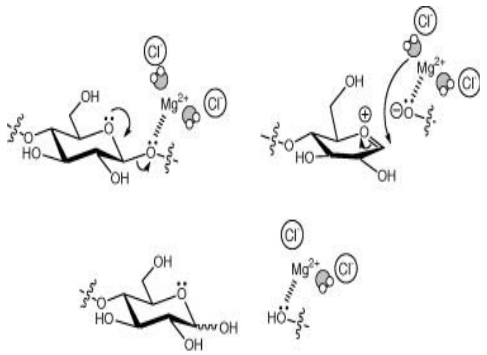

Figure 1 : Cationization of the treated fabric with $MgCl_2$

f) Dyeing process

Dyeing of the pretreated union fabrics were carried out in the laboratory dyeing machine by the pad method. The unmodified and modified fabrics were dyed with (4% owf) Acid red C.I. 108 as shown in Figure.2 in a bath containing (8%owf) Amonium acetate and (4% owf) hydrochloric acid 30%, with with a liquor ratio of 1:20.

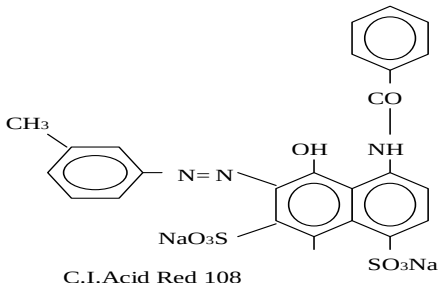

Figure 2 : Chemical structure of C. I Acid Red 108

Firstly, salt and acid were added to water and the dyeing bath was warmed at 50° C, then the samples were immersed in the dyeing bath and the dyeing continued for 10 min., followed by adding the dye solution and the dyeing continued for 15 min., then the temperature was raised to boiling through 20 min, the dyeing was continued at this temperature for (45 min). finally the dyeing was stopped and the dyeing bath was cooled. Dyed samples were thoroughly rinsed with running cold water, then soaped with a solution containing 5g/l nonionic detergent (Hostapal CV-ET) and 1g/l Na_2CO_3 at 40°C for 15 min, Soaping were carried out for 4 times to ensure good washing fastness. Finally rinsing with hot and cold water after wash the samples were left air dried.

III. Measurements

a) Dyeability measurements

The color strength (K/S) of the treated samples using the untreated samples as blank was determined using perkin Elmer spectrophotometer, Model Lambada35 equipped with integrated sphere according to Kubelka- Munk equation].

$$K/S = (1-R)^2 / 2R$$

Where:-

R: Decimal fraction of the reflectance of dyed samples.

K: Absorption coefficient.

S: scattering coefficient

The color components L,a, and b were measured according to CIE L*, a* , b*. ASTM E 308-96, computing the colors of object by using the CIE system.

Total color difference (ΔE), hue (h) and chroma (c) were computed by spectrophotometrical determine by using the following equations:

$$\Delta E = \sqrt{(L_2^* - L_1^*) + (a_2^* - a_1^*)(b_2^* b_1^*)}$$

$$C_1^* = \sqrt{a_1^{*2} + b_1^{*2}}$$

$$h_{ab} = C.\ Tan\ b / a$$

Where (L_1^* , b_1^* , a_1^*) of reference color , (L_2^* , b_2^* , a_2^*) of target color.

b) Estimation of bursting strength

The bursting strength of the knitted fabrics were determined by the standard method ASTM D 3787- 07, Air permeability was determined by the standard procedure ASTM D737-04 (2008), thickness was determined by the standard procedure ASTM D 1777-96 (2007), and the Abrasion was determined by the standard procedure Martindale ASTM D 4157- 10.

c) Fastness properties

Washing fastness of the dyed samples was done according to the AATCC test method 16-1972. Fastness to synthetic perspiration was measured according to ISO-E04: 1994. Fastness of light was measured according to the ISO 105:1997 using standard wool gray scale as reference in all testes.

IV. Results and Dicussions

a) Color measurements of the cotton/nylon blends

It has been observed that the color measurements have the lowest values of cotton as shown in table 2. This was because cotton fibers when immersed in water produce a negative zeta potential

and most of the dye classes suitable for cotton are anionic in nature. The negative charge on the fiber repels the C. I Red 81 dye ions and consequently the exhaustion of the dye bath s limited which lead to the decrease of the color measurements. Also, as the CAA treatment increase the negative charge into cotton, the color measurement decrease. On the other hand, the color measurements of nylon were limited due to the competition of CAA and C. I Red 108 dye ions to react with the positive charge of amide group of nylon. The large differences between the color measurements values of the nylon/cotton knitted fabrics may also arise from the differences of the molecular structure of the fibers. It is well known that the diffusion of dye molecules into fibers mainly depends on the size and distribution of the crystalline (ordered) and amorphous (disordered) regions. The color measurements of cotton/nylon blends increased with the cationization with magnesium chloride. Magnesium chloride reacts with the negative charges present on cotton/nylon blend surface. The C. I Red 108 anionic ions react with the positive charges of the blends and the color measurements increased. The variation of the color measurements of the different blend ratios was due the ability of the anionic dyes to react with the positive charges present due to the surface area and the number of pores present. It has been pointed out that the highest chroma (measures color saturation) values indicate that the cotton/nylon 75:25% fabrics are dyed with the highest saturation and the colors obtained are the brightest. The values of the hue angle (runs between 0 and 360◦ measures color range and the angles of 0◦, 90◦, 180◦, 270◦ refers to red, yellow, green, and blue shades respectively) showed that all the samples were closer to red color. The highest h values of the cotton/nylon 75:25% fabrics indicate that these fabrics have the reddest appearance.

Table 2 : Color measurements of the cotton/nylon blends dyed

Samples	K/S	L	a	b	ΔE	C	h
Cotton 100%	4.22*	44.9	23.5	1.9	50.7	23.5	4.6
	7.27**	39.9	27.6	3.75	48.1	27.8	7.7
Cotton/ nylon 25:75%	7.90	37.2	32.5	2.3	49.4	32.6	5.6
	8.20	34.9	26.8	5.8	53.5	27.4	12.2
cotton /nylon 75:25%	4.52	34.3	24.5	1.7	42.1	24.5	3.9
	5.95	39.1	29.8	4.8	49.4	30.1	9.1
cotton /nylon 50:50%	5.70	43.1	21.1	3.7	48.1	21.4	20.1
	6.20	50.6	20.5	3.64	54.6	20.8	10
Nylon 100%	4.30	37.77	26.20	1.8	52.9	25.3	3.2
	6.30	39.47	24.20	3.8	49.9	28.3	6.2

**Treatment of the blend with CAA ** Treatment of th e blend with $MgCl_2$*
Dyeing bath: Acid red C.I 108 (4%), temp: 50°C, time: 90 min, L.R.1:50

b) Mechanical properties of cotton/nylon blends

The results obtained in Table 3 revealed that the bursting strength of cotton 100% and nylon 100% decreased after the cationization treatment. Bursting strength increased with the increase of the nylon percent in the blend. The highest values for the treated sample Cotton/ nylon 25:75% is 614. Blends containing less than 50% nylon were actually weaker than all-cotton yarns. Owing to the lower modulus of the nylon, the load on the yarn as it was extended was increasingly borne by the cotton fibers in the blend. This was due to the bleaching nylon/cotton blends with hydrogen peroxide at the boil. The amount of peroxide affect the proportion of nylon present and an oxidative damage of the nylon occurred lowering the bursting strength of the blends. A greater relative increase in air permeability was observed with increasing synthetic fiber content. It was concluded that air permeability of

cotton /nylon 25:75% fabrics was found to be higher by about 20-25% than other blends. The cotton/nylon blended fabrics also exhibited higher air permeability values as compared to cotton fabrics. It also pointed out that nylon reduces the weight of the fabric and increases its air permeability. The abrasion resistance of nylon 6, 6 was higher than cotton. The abrasion resistance increase as the nylon ratio increased in the blend.

Table 3 : Mechanical properties of cotton/nylon blends

Samples	Bursting Strength kg/cm^2	Thickness mm	Air permeability cm^3/cm^2/sec	Abrasion resistance
100%cotton	530.00*	1.6	57	220
	468.00**	1.5	61	117
25%cotton:75%nylon	616.00	1.1	88.3	288
	688.00	1. 0	100.3	397
75%cotton:25%nylon	409.00	1.4	67.3	154
	514.00	1.3	80.3	258
50%cotton:50%nylon	493.00	1.25	84.7	207
	663.00	1.2	91.3	356
100%nylon	1000.00	0.91	149.3	455
	892	0.96	122.1	412

**Treatment of the blend with CAA ** Treatment of the blend with $MgCl_2$*

c) Fastness properties of cotton/nylon blends

It can be seen from Table 4 that the wash fastness gave the similar ratings between 3/4 and 4/5. The staining tendency on the adjacent fabrics is much less, the fastness showed such good performance that it may be due to the mineral matter present on the cotton fabric. The metal salts which might be forming chelates with the dyes inside the substrates. Acidic and alkaline samples show good -very good (3/4- 4/5) with respect to color change, however, staining of the adjacent fabric is to some extent high of dyed samples. It can be seen that the light fastness ratings between (3/4 -6) with respect to color change, however, staining of the adjacent fabric is to some extent high of dyed samples.

As in the case of the wash fastness results, no shade changes are observed for the all fabrics after the perspiration fastness tests. In terms of staining, the acidic perspiration fastness results of all the fabrics are better than the alkali perspiration results. Fiber type seems to have no significant effect on the acidic perspiration results. The light fastness results of all the fabrics are good. The highest light fastness result of the cotton/nylon fabrics may be attributed to the natural UV resistant property of nylon fibers as stated previously in the study of Sheshachala et al.2008. In general, deeper and darker colors usually lead to an increase in the light fastness results of fabrics. Therefore, the deepest and darkest colors of the nylon/cotton fabrics, due to the highest K/S and the lowest L* values, may also the other reason for the highest light fastness results of these fabrics.

Table 4 : Fastness properties of cotton/nylon blends

Samples	Washing fastness 40°C		Perspiration fastness				Light fastness
			Acidic		Alkaline		
	Gray	Stain	Gray	Stain	Gray	Stain	
100%cotton	3/4	4/5	3/4	4	4	4	3/4
	4/5	4	4	4/5	4	4	4/5
25%cotton:75%nylon	5	4/5	5	5	5	5	5
	5	4/5	4/5	4	4/5	4	4
75%cotton:25%nylon	4/5	4/5	4/5	4	4/5	4/5	4/5
	3/4	4/5	3/4	3/4	3/4	4	3/4
50%cotton:50%nylon	4/5	4/5	4/5	4	4	4/5	4/5
	4/5	5	4/5	4	4	4	4/5
100%nylon	5	5	5	5	5	5	6
	5	5	5	5	5	5	6

**Treatment of the blend with CAA ** Treatment of the blend with $MgCl_2$*

V. Conclusions

This researchdescribed the ability to dye cotton/nylon blends in one step, one dyeing bath after the treatment of the fabric with the anionic chloroacetic acid followd by the cationization of the fabric with magnesium chloride. The results obtained revealed that the cotton/nylon 75:25% have the highest color measurement values, highest color fastness, while cotton/nylon 25:75% represented the highest air permeability, and the highest abrasion resistance. The process featured shortened time and saved cost.

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